ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to all those who have supported and guided me for the course of this research work on **"Volatile Organic Compound Profiling with Biomarkers for Early Lung Cancer Detection Using the ODOScan E-Nose System."**

First and foremost, I extend my sincere thanks to my esteemed guide, **Dr. Sarita Ambadekar**, for her constant encouragement, expert guidance, and valuable insights at every stage of this research. Her mentorship has been invaluable in shaping the direction and depth of this work .I am also deeply grateful to **Dr. Hariram Chavan**, Ph.D. Coordinator, for his continuous support, constructive suggestions, and guidance throughout the research process. His experience and vision have played a significant role in refining the scope and methodology of this project. I would like to express my sincere appreciation to our respected **Principal**, for providing the necessary academic environment, infrastructure, and encouragement to carry out this research at **K. J. Somaiya Institute of Technology, Sion, Mumbai**.

Lastly, I am deeply thankful to my family and friends for their unwavering support, patience, and belief in me throughout the completion of this research.

Jamkar

Nisha Ganesh Jamkar

Registration No: 2220240797

INDEX

Abstract		i
List of Figures		ii
List of Tables		iii
1	Aim of the Study	1
2	Study background (Literature review) and Significance of Study	2
3	Objectives of Study	8
4	National Status	8
5	International Status	9
6	Study Hypotheses	10
7	Study Rationale	11
8	Research Methodology	11
9	Statistical plan	15
10	Limitations of the Study	15
11	Expected Outcomes of the Study	16
12.	Bibliography	17
13	Appendix	21

ABSTRACT

Digital olfaction systems are an emerging class of technologies that mimic the human sense of smell by detecting, processing, and interpreting volatile organic compounds (VOCs) using sensors and artificial intelligence. These systems have shown immense potential in applications ranging from food safety, agriculture to disease diagnosis, enabling non-invasive, real-time analysis of complex gas mixtures.

Early detection of lung cancer significantly improves treatment outcomes, yet current diagnostic methods remain invasive, costly, and inaccessible in many settings. This study presents *ODOScan*, a non-invasive electronic nose (e-nose) system designed to profile volatile organic compounds (VOCs) in exhaled breath for early lung cancer detection. By simulating human olfaction, ODOScan leverages a sensor array to detect disease-specific VOC biomarkers and applies machine learning algorithms for pattern recognition and diagnosis. The system integrates with an Android application to provide real-time screening results, enhancing usability in clinical and remote environments. The diagnostic models are validated using breath samples and supported by clinical feedback, demonstrating the potential of VOC-based digital olfaction as a reliable, portable, and cost-effective tool for early cancer detection. ODOScan aligns with India's innovation priorities in low-cost, accessible diagnostics and is currently in the prototype validation stage. Its potential lies not only in early detection but also in mass screening applications, especially in resource-constrained settings. The system aims to bridge the gap between clinical need and technological capability in lung cancer diagnostics.ODOScan integrates these advancements into a compact and user-friendly device, offering a cost-effective, non-invasive platform for rapid screening in both clinical and remote healthcare environments.

LIST OF FIGURES

Fig. No	Figure Name	Page No.
5.1	Breath Sampler	9
5.2	NA-Nose	10
5.3	E-Nose	10
8.1	Proposed Methodology	12
8.2	5C-SSM Sensor	13
8.3	Bar Graph	14

LIST OF TABLES

Table No	Table Name	Page No.
2.1	Comparative Analysis of Various Papers	4
8.1	Example of Disease Specific VOCs	12
9.1	Statistical Plan for next three years	15

1. Aim of Study

To develop and validate a portable electronic nose (e-nose) system, ODOScan, for early detection of lung cancer through VOC profiling, with a specific focus on enhancing diagnostic accuracy using benzene as a key biomarker.

1.1. Introduction

Lung cancer continues to be a leading cause of cancer-related mortality worldwide, largely due to delayed diagnosis and limited access to early screening techniques[1]. Traditional diagnostic tests such as low-dose computed tomography (LDCT) and tissue biopsies, although clinically relevant, are often invasive, costly, and impractical for population-wide implementation—particularly in low-resource settings.

Breathomics, the study of volatile organic compounds (VOCs) in exhaled breath, presents a compelling non-invasive alternative for early detection of lung cancer [2]. VOCs such as benzene, toluene, acetone, isoprene, pentane, and formaldehyde have been identified as relevant biomarkers, reflecting metabolic alterations and environmental exposures associated with malignancy. Benzene, specifically, has been shown to correlate strongly with tobacco-related carcinogenesis and displays elevated concentrations in the breath of lung cancer patients [3]. Its integration enhances diagnostic specificity and can improve early detection rates.

In this context, the present study introduces ODOScan, a novel Indian-developed electronic nose (e-nose) platform engineered for benzene-enhanced VOC profiling. The device combines a carefully designed MOS sensor array, signal processing modules, and machine learning classification to differentiate lung cancer breath signatures from healthy controls. Inspired by proven models and validated by recent multi-center trials [1], ODOScan aims to deliver an affordable, portable, and accurate solution for early lung cancer screening—particularly valuable in low-resource environments and preventive health contexts.

2. Study background (Literature review) and Significance of Study

2.1 Comparative Analysis of research papers

Recent advancements in non-invasive diagnostic technologies have highlighted the potential of exhaled breath analysis in detecting diseases at early stages. This approach primarily focuses on identifying volatile organic compounds (VOCs), which reflect physiological and pathological states in the human body. Dragonieri et al. [13] explored the application of electronic nose (e-nose) technology to distinguish between asthma and chronic obstructive pulmonary disease (COPD). Gowda, Dessai, and Nayak [14] describe this technology as a "non-invasive diagnostic revolution," particularly for lung cancer, due to its capacity to detect distinct VOC signatures without invasive procedures, The findings demonstrated that specific VOC patterns in exhaled breath could be reliably used to differentiate these respiratory disorders. Similarly, Leja et al. [15] discussed the promise of breath biopsy in the early diagnosis of cancer and infectious diseases. The technique captures and analyzes breath VOCs, offering a non-invasive, real-time diagnostic method. While Ma et al.[16] showed success of e-noses in gastrointestinal applications, their findings affirm the broader potential of VOC analysis for internal diseases. This hardware innovation supports real-time processing and makes the system suitable for point-of-care diagnostics. Sharma, Kumar, and Varadwaj[17] further emphasized the diagnostic potential of breath analysis, reinforcing that breath VOC profiling can help detect disease at an earlier stage than conventional imaging or biopsy. On the technical front, Abideen et al.presented emerging advancements in metal oxide-based e-noses, which form the backbone of many modern diagnostic sensors, including those used in cancer screening [18].

These devices have demonstrated high sensitivity and specificity in distinguishing lung cancer from other respiratory conditions and healthy controls. Additionally, the review discusses the potential of e-noses to monitor treatment response, although results in this area remain less consistent due to limited studies and methodological variation. Despite promising outcomes, the review highlights challenges such as the lack of standardized sampling protocols, sensor calibration, and the need for large-scale clinical validation. Electronic nose (e-nose) systems, which mimic the mammalian olfactory system, have gained recognition for their potential to non-invasively detect lung cancer through the analysis of volatile organic compounds (VOCs) in exhaled breath. Vadala et al. [19] highlighted that e-noses are not only effective in detecting lung cancer but also in monitoring treatment responses, offering real-time insights into patient progress and relapse detection. Overall, the study supports the advancement of e-nose technology as a rapid, portable, and cost-effective solution for early lung cancer. Huang Y et al. [20] introduces a portable e-nose integrated with machine learning algorithms, enhancing real-time gas detection with improved accuracy and low power consumption. Karakaya D. et al. [21] provides an extensive overview of electronic nose (e-nose) systems,

which are devices designed to mimic the human olfactory system for the detection and identification of odors and volatile compounds. The authors describe the key components of e-noses, including sensor technologies (such as MOS, CP, QCM)data acquisition units, and pattern recognition algorithms.

The review highlights diverse application areas like healthcare (disease diagnosis via breath analysis), food quality control**,** environmental monitoring**,** and industrial safety**.** It also discusses challenges like sensor drift, reproducibility, and the need for miniaturization and enhanced data processing. Dennler et al. [22] introduce a miniaturized electronic nose designed for ultra-high-speed odor detection**,** achieving temporal resolutions previously unseen in low-power portable systems. The device, roughly the size of a credit card, utilizes high-bandwidth gas sensors**,** rapid thermal control, and advanced algorithms to classify odor pulses within tens of milliseconds, matching or exceeding the speed observed in mice, operating at odor-switching frequencies up to 60 Hz .Applications span healthcare**,** robotics**,** environmental monitoring**,** and industrial safety. The system's rapid response and compact design make it highly suitable for mobile odor-source localization tasks and real-time sensing in unmanned systems. Broza et al. [23] demonstrates how a nanomaterial-based e-nose can detect COVID-19 via exhaled VOCs with high accuracy, showcasing the power of breath diagnostics for infectious diseases. Van der Sar et al.[24] deliver a comprehensive review of electronic nose applications for lung disease diagnosis and monitoring. They detail how e-nose–derived VOC breathprints have shown high sensitivity and specificity in differentiating lung cancer, asthma, COPD, and interstitial lung disease. The review evaluates sensor technologies and machine learning approaches, while underlining critical challenges—such as inconsistent sampling protocols, variability across devices, and limited external validation—that currently impede widespread clinical implementation. Fens et al. [25] demonstrates that breath VOC profiling using sensor arrays can accurately differentiate between COPD and asthma, improving differential diagnosis in respiratory medicine. Chen & Zheng [26] explores the development of an e-nose tailored to colorectal cancer detection, proposing it as a non-invasive, supplementary screening method for early intervention. Yuting Ji et al. [27] presents a comprehensive analysis of the epidemiological landscape of lung cancer using the most recent data from GLOBOCAN 2022. The study highlights the current global incidence, mortality rates, and the projected trends of lung cancer over the coming decades. Amal Hossam et al.[28] developed and validated a nanomaterial-based breath test capable of distinguishing between gastric cancer, precancerous lesions, and benign gastric conditions. Using nano array sensors and confirmatory GC-MS, the test achieved ~92% diagnostic accuracy, ~98% specificity, and ~73% sensitivity in a large cohort of 484 subjects, demonstrating its robustness against confounders like smoking or H. pylori infection.

These studies collectively underscore the increasing focus on breathomics and sensor fusion technologies in medical diagnostics. While multiple solutions exist, a significant gap remains in achieving high accuracy,

portability, and real-world clinical integration—all of which this study aims to address through the development of ODOScan.

Table 2.1 Comparative Analysis of Various Papers

Author/s	Title	Methodology	Research Gap
Van den Vries et al.	Lung cancer detection by electronic nose analysis of exhaled breath: A multicenter prospective external validation study	Conducted a multicenter, prospective external validation of an e-nose diagnostic model across various clinical centers, involving real-world outpatient cohorts.	Limited prior e-nose studies lacked extensive external validation or real-world applicability; standardization across centers was previously inadequate.
Burger et al.	Electronic-nose technology for lung cancer detection: A non-invasive diagnostic revolution	Comprehensive review of e-nose technologies, VOC biomarkers including benzene, and machine learning pipelines in lung cancer detection studies.	Existing literature has variable methodologies and lacks unified standards for biomarker selection, sampling, and data processing.
Kononov, A. et al. (2020)	Online breath analysis using metal oxide semiconductor sensors (electronic nose) for diagnosis of lung cancer	Developed and tested an online real-time breath analysis system using MOS (metal oxide semiconductor) sensors for non-invasive lung cancer detection. Utilized machine learning classifiers for pattern recognition of VOC profiles.	Although promising, the system lacked large-scale clinical validation and standardized sensor calibration methods, limiting its translational use in hospitals.
Kim C., et al.	Recent Trends in Exhaled Breath Diagnosis Using an Artificial Olfactory System.	Provided a comprehensive review of artificial olfactory systems (e-noses) for exhaled breath diagnosis, discussing sensor types (metal-oxide, polymer-based, CNTs), data processing techniques (AI/ML), and clinical applications in diseases such as cancer, diabetes, and infections.	Most artificial olfactory systems still lack clinical standardization and large-scale validation. There is a need for real-time, portable, low-cost solutions with improved selectivity and robustness under complex breath conditions.
Yuting Ji, et al.	The epidemiological landscape of lung cancer: current status,	Provides an updated epidemiological analysis of lung cancer using GLOBOCAN 2022 data, highlighting global incidence, mortality rates, geographical	While the paper offers robust statistical forecasting, it does not address integration of early diagnostic tools (e.g., VOC-based breath analysis)

	temporal trend and future projections based on the latest estimates from GLOBOCAN 2022.	disparities, and future projections to 2040. Emphasizes increasing burden in low- and middle-income countries.	in national screening policies. Future studies could explore how novel technologies may reduce incidence and mortality through early detection.
Tang, K.-T. and Chiu, S.-W.	A low-power electronic nose signal-processing chip for a portable artificial olfaction system, IEEE Transactions on Biomedical Circuits and Systems.	Designed and implemented a low-power, compact signal-processing chip for an artificial olfaction (e-nose) system. The system includes a gas sensor interface, analog signal processing, and digital classification using k-nearest neighbor algorithm — suitable for portable and embedded diagnostic applications.	Although the chip is optimized for low power and size, it was tested only on a limited gas set. It lacks integration with advanced machine learning models and was not validated on complex VOC mixtures such as human breath samples relevant to medical diagnostics.
Jan E. Szulejko; et al.	Evidence for Cancer Biomarkers in Exhaled Breath	Review of VOC analysis methods for cancer detection	Provided early evidence linking specific VOCs in breath to various cancers
Zeh G., et al.	Towards Artificial Intelligent Olfactory Systems	Conceptual framework combining gas sensors with AI/ML classification; system architecture proposed for digital olfaction algorithms for real-time odor	Conceptual framework combining gas sensors with AI/ML algorithms for real-time odor classification; system architecture proposed for digital olfaction
Mc Williams, et al.	Training and validating a portable electroni*c nose for lung cancer screening*	Used a portable e-nose system to collect and analyze breath samples from high-risk individuals, applying statistical models for validation.	While showing promise, the study did not isolate specific VOC biomarkers Performance across diverse populations.
Yager P. et al.	Point-of-Care Diagnostics for Global Health	Advocated biosensors and mobile tech for early diagnosis	Support development of low-cost breath diagnostics globally
Esteva A. et al.	A Guide to Deep Learning in	Demonstrated DL use in pattern recognition across medical data	Apply DL to VOC data and non-image diagnostic

	Healthcare		streams
Balarajan Y., elvaraj S.& Subramanian S. V.	Health care and equity in India	Conducted a policy and data analysis using national health surveys and socioeconomic datasets to evaluate health care disparities in India.	Identified deep-rooted inequities in healthcare access but did not explore technology-based solutions like e-health or diagnostics.

2.2 Significance of Study:

A growing body of literature highlights the transformative potential of e-nose technologies in non-invasive disease diagnosis, particularly through the analysis of volatile organic compounds (VOCs) in exhaled breath. Recent advances in electronic nose (e-nose) technology have shown promising applications in the non-invasive detection of lung cancer through volatile organic compound (VOC) profiling. Van den Vries et al. [1] conducted a multicenter prospective external validation study confirming that e-nose analysis of exhaled breath can distinguish lung cancer patients from healthy controls with high sensitivity, reinforcing its potential as a frontline screening tool. Similarly, Burger et al. [2] highlighted how sensor-based breath analysis, when combined with machine learning algorithms, can be effectively used to detect early-stage lung cancer.

Kononov et al. [3] developed an online breath analysis system using metal oxide semiconductor (MOS) sensors, demonstrating its feasibility in real-time lung cancer detection by identifying unique cancer-related VOC patterns. Kim et al. [4], in *"*Artificial olfaction for disease diagnosis via exhaled breath*,"* emphasized the rapid technological advancements enabling e-nose systems to effectively detect disease-specific VOC profiles. Yuting Ji et al. [5] outlined the global burden of lung cancer in *"*The epidemiological landscape of lung cancer*"*, reinforcing the urgent need for early diagnostic interventions like breath-based screening tools. The foundational work by Tang and Chiu [6] introduced a *"*Low-power electronic nose signal-processing chip*"*, enabling portable olfactory systems and setting the stage for point-of-care diagnostics. Szulejko et al. [7], in their comprehensive review of exhaled breath biomarkers, highlighted VOCs' diagnostic promise in oncology. Similarly, Zeh et al.[8] discussed the integration of AI in olfactory systems, advancing e-nose capabilities in *"*Towards Artificial Intelligent Olfactory Systems*."*

McWilliams et al. [9] validated a portable e-nose for lung cancer screening, while Yager et al. [10] stressed the relevance of low-cost, decentralized diagnostic tools in underserved regions. Esteva et al. [11] supported this approach by exploring deep learning applications in healthcare, directly applicable to the data interpretation challenges in e-nose platforms.

From a public health perspective, Balarajan et al.[12] highlighted systemic inequities in healthcare access in India, advocating for affordable and scalable diagnostic solutions such as breath sensors. Clinically,

Dragonieri et al. [13] demonstrated the capacity of e-noses to differentiate between asthma and COPD cases, supporting their broader respiratory diagnostic utility. Gowda et al. [14] further illustrated the utility of e-noses in monitoring lung cancer treatment response.

In gastrointestinal oncology, Leja et al.[15] and Amal et al.[28] confirmed e-nose efficacy in detecting gastric cancer via exhaled breath, while Ma. et al. [16] extended this to colorectal cancer detection using nanomaterial-based sensors. Sharma et al. [17] discussed the emergence of breathomics as a promising frontier in personalized diagnostics, and Abideen et al. [18] provided a detailed analysis of metal oxide semiconductor (MOS) sensor innovations crucial to disease-oriented e-noses. Vadala.et al. [19] focused on real-time monitoring of therapeutic response in lung cancer using breath VOCs, while Huang et al.[20] demonstrated the feasibility of lightweight, AI-enabled e-noses in clinical workflows. Broad overviews by Karakaya et al.[21] examined e-nose system architecture, sensor technologies, and application domains across healthcare, food safety, and environmental monitoring. On the engineering front, Dennler et al[22]. showcased a miniaturized e-nose optimized for high-speed odor sensing in medical and robotic settings. Pandemic applications were explored by Broza et al.[23], who successfully used nanomaterial sensor arrays to detect COVID-19 from exhaled breath. Disease-specific reviews by van der Sar et al.[24] and Fens et al. [25] summarized progress in detecting lung diseases—including asthma, COPD, and cancer—using breath VOCs, while Chen et al. [26] contributed evidence for colorectal cancer screening using breath-based sensor arrays. Finally Yuting Ji et al. [27] provide an updated global overview of lung cancer epidemiology using GLOBOCAN 2022 data, highlighting rising incidence rates and forecasting an increasing burden in low- and middle-income countries. They emphasize the urgent need for improved early detection and prevention strategies. In parallel, Amal et al.[28] demonstrate that nanomaterial-based sensor arrays can detect precancerous and cancerous gastric conditions through exhaled breath analysis. Their study supports the potential of non-invasive, VOC-based diagnostics for early cancer detection. Together, these works underscore the importance of innovative, accessible screening tools to address the growing global cancer burden.

3. Objectives of Study:

1. **To design a non-invasive diagnostic device integrated with an Android application for early disease screening.**

   This involves creating a user-friendly medical device that detects diseases through breath analysis and displays results on an Android app, enabling accessible and early diagnosis without the need for invasive tests.

2. **To digitally emulate human olfaction by analyzing exhaled VOCs using sensor technology and machine learning.**

   The system mimics the human sense of smell using an array of chemical sensors and algorithms that identify patterns in volatile organic compounds (VOCs) to detect disease-specific signatures. By collecting breath samples from both healthy and affected individuals, the project aims to train and test machine learning models that can accurately predict disease presence based on biomarker patterns.

3. **To validate diagnostic models using VOCs and biomarkers with clinical support**

   This objective focuses on verifying the accuracy of predictive models based on breath biomarkers, with validation assisted by medical experts to ensure clinical relevance and reliability. The developed models will be tested using real patient data and further validated through feedback from medical professionals. This ensures the system's diagnostic reliability aligns with clinical expectations.

4. National Status:

ODOScan is an emerging Indian diagnostic innovation designed to detect disease-specific VOCs in exhaled breath, using electronic nose (e-nose) technology integrated with machine learning algorithms. The development of ODOScan aligns with India's recent surge in non-invasive diagnostic research, as seen in projects by premier institutes. For instance, researchers at IIT Roorkee developed an affordable breath-based device (BLO Detector) capable of detecting lung, breast, and oral cancers with over 94% accuracy, in collaboration with Tata Steel and supported by clinical trials [26].

Similarly, IIT Bombay pioneered a nanotechnology-enabled platform for detecting lung cancer from breath VOCs [27], and IIT Kanpur introduced a portable sensor-based system for continuous lung health monitoring Inspired by these nationally recognized models, ODOScan is in the prototype validation stage and aims to advance through incubation, IP filing, and clinical trials. Its roadmap aligns with innovation frameworks under BIRAC, ICMR, and Startup India, with the goal of contributing to India's affordable and accessible healthcare technology ecosystem [28].

5. International Status:

Globally, there is growing recognition of breath-based diagnostics as a promising, non-invasive approach to early disease detection. International research institutions and medical technology companies are actively exploring the potential of VOCs as biomarkers for various diseases, including lung cancer, colorectal cancer, asthma, tuberculosis, and infections.

Breath-based diagnostics are gaining momentum globally, with academic institutions and companies developing non-invasive systems to detect diseases via exhaled VOCs Leading initiatives include:

5.1. Owlstone Medical – Breath Biopsy

- **Technology:** FAIMS-based VOC detection integrated with AI [35]
- **Use Case:** Early detection of lung, liver, and other diseases in clinical research and hospitals
- **Strengths:** High sensitivity and reliability; used in major trials
- **Limitations:** Not portable; costly infrastructure; not suited for rural or point-of-care deployment.

fig. 5.1 Breath Sampler

5.2. Technion (Israel) – NA-Nose

- **Technology:** Gold nanoparticle-based chemiresistive sensor array (nano-AI nose)
- **Use-Cases:** Achieved ~92–95% accuracy in distinguishing lung and head-neck cancers (tested on 62–100 subjects)
- **Commercialization:** Licensed to Alpha Szenszor; device priced at ~$10,000/unit
- **Strengths:** Clinically validated with strong accuracy
- **Limitations:** High cost; scalability for mass screening in underserved areas still under development

fig.5.2 NA-Nose

5.3. Memorial Sloan Kettering Cancer Center (MSKCC) – E-Nose Trials

- **Technology:** AI-powered VOC detection in breath
- **Use Cases:** 86% agreement with biopsy-confirmed lung cancer cases
- **Limitations:** Research-grade deployment; not yet commercialized widely

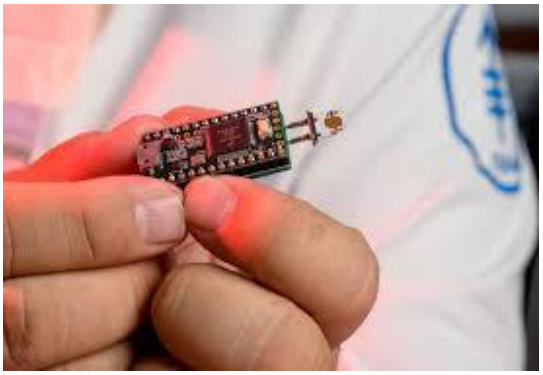


fig. 5.3 E-Nose

6. Study Hypothesis:

1. Null Hypothesis (H_0): There is no significant difference in the VOC profiles of lung cancer patients and healthy individuals; ODOSCAN cannot reliably distinguish between them.
2. Alternative Hypotheses (H_1): VOCs differ significantly in lung cancer patient vs. healthy individuals.

7. Study Rationale:

Lung cancer continues to be one of the leading causes of cancer-related mortality globally due to its asymptomatic nature in early stages and the lack of accessible, non-invasive screening tools [5]. Breath analysis using electronic nose (e-nose) systems has emerged as a promising approach, offering rapid, real-time detection of disease-specific volatile organic compounds (VOCs) [1], [2], [3]. Several studies have demonstrated that VOC profiles differ significantly between healthy individuals and lung cancer patients, particularly in compounds like acetone, isoprene, formaldehyde, and benzene derivatives [7], [23], [30].

This study is significant as it proposes a novel integration of e-nose technology with machine learning algorithms to enhance diagnostic accuracy and enable early detection. Specifically, it focuses on benzene, a VOC with demonstrated diagnostic relevance but limited coverage in current breath analysis research [23], [30]. By validating the ODOScan system as a portable, low-cost, and non-invasive tool, this research contributes to bridging the translational gap between experimental diagnostics and clinical deployment [6], [9], [25]. Furthermore, the study builds on epidemiological projections that emphasize the urgent need for scalable early screening tools for lung cancer [5].

Ultimately, this research aligns with the global objective of shifting from reactive to preventive oncology by enabling earlier, faster, and more accessible lung cancer diagnosis through breath-based VOC analysis [4], [8], [27].

8. Research Methodology:

The development of the ODOScan system begins with the careful selection of sensors that are sensitive to disease-specific volatile organic compounds (VOCs). Metal-oxide semiconductor (MOS) sensors, quartz crystal microbalance (QCM), and 5C solid-state sensor modules (SSM) are considered for their sensitivity, compactness, and cost-effectiveness in gas detection applications [6]. These sensors are integrated with a microcontroller platform, such as Arduino or ESP32, to interface with the sensor array and manage signal flow. To ensure accurate signal interpretation, dedicated signal conditioning circuits and high-resolution analog-to-digital converter (ADC) modules are designed for low-noise and precise data acquisition [31].

On the software side, firmware is developed to enable real-time data acquisition and communication between hardware components. Machine learning algorithms are implemented to filter signal noise, normalize sensor output, and improve detection accuracy, forming the core of the system's breath-profile analysis capability [4]. A local data storage infrastructure is also developed to support offline analysis and future integration with cloud-based diagnostic platforms [5].

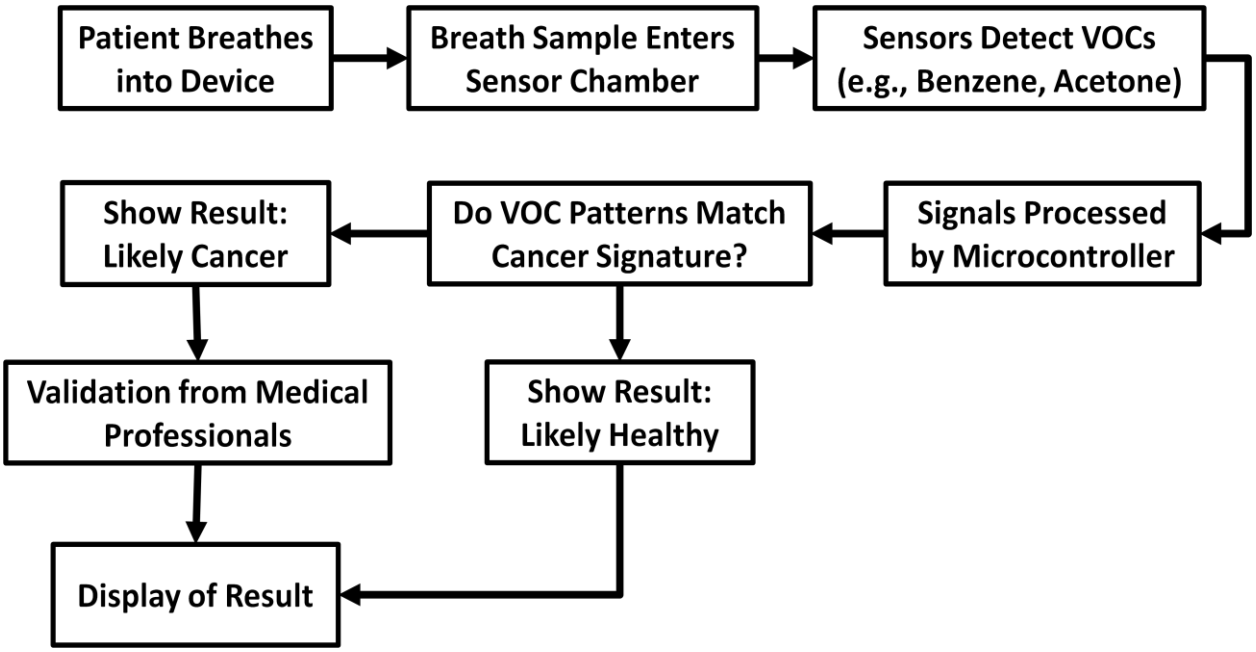

Patient Breathes into Device
Breath Sample Enters Sensor Chamber
Sensors Detect VOCs (e.g., Benzene, Acetone)
Signals Processed by Microcontroller
Do VOC Patterns Match Cancer Signature?
Show Result: Likely Cancer
Validation from Medical Professionals
Show Result: Likely Healthy
Display of Result

fig. 8.1 Proposed Methodology

1) Breath Sample Collection

Participants for the study include both healthy individuals and patients diagnosed with specific diseases such as lung cancer. Each participant exhales into the ODOScan device, which captures their breath sample. The exhaled breath contains VOCs that may serve as biomarkers for various health conditions. The following table 8.1 presents a comparison between the VOCs found in the exhaled breath of healthy individuals and those observed in patients with disease conditions**.**

Table 8.1: Example of Disease-Specific VOCs [4]

Sr. No	Biomarkers	In Healthy Person	In Cancer Patient
1	Acetone	627.5 ppb	458.7 ppb
2	Formaldehyde	Below 48 ppb	83 ppb
3	Ethane	0.5 to 5 ppb	7.6 ppb
4	Pentane	1.73 to 17.50 ppb	0.12 ppb
5	Isoprene	89.32 to 185.72 ppb	81.5 ppb
6	Ethanol	0.00 ppb	0 to 1663 ppb

(Note: Part per billion (ppb))

In addition to the above-listed volatile organic compounds (VOCs), **benzene** has also emerged as a

significant biomarker in breath analysis for lung cancer detection. While healthy individuals typically exhibit benzene concentrations **ranging from 0.020 to 0.080 ppb,** primarily due to environmental exposure (such as air pollution or tobacco smoke), studies have shown that lung cancer patients often demonstrate markedly elevated levels, **ranging from 0.150 to 0.500 ppb.**

This increase is likely due to oxidative stress and altered metabolic activity associated with malignant tissues. Therefore, benzene, when analyzed alongside other VOCs like acetone, formaldehyde, and isoprene, enhances the diagnostic potential of non-invasive breath-based detection systems [29][30][31].

2) Sensor Data Acquisition

The breath sample passes through a sensor chamber containing an array of gas sensors (typically metal-oxide semiconductor sensors). These sensors detect the presence and concentration of VOCs and convert the chemical signals into measurable electrical signals. The data is digitized and stored for analysis. The image illustrates the 5C Solid-State Metal Oxide (SSM) Sensor, a compact and highly sensitive module used for detecting VOCs in exhaled human breath.

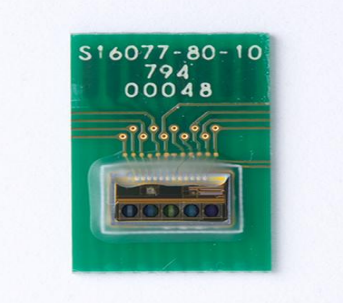


fig 8.2. 5C SSM Sensor [30]

3) Signal Processing

The raw signals from the sensors are first filtered to eliminate noise and reduce variability. Normalization techniques are applied to standardize the data across different samples. Key features such as mean sensor response, peak values, and response duration are extracted for use in classification.

4) Machine Learning Classification

The extracted features are used to train machine learning models such as Support Vector Machines (SVM), Random Forest, or Neural Networks. These models are trained on a labeled dataset and then

tested using validation techniques like k-fold cross-validation to ensure accurate classification of breath samples into healthy or diseased categories.

5) **Result Output and Ethical Considerations:** The diagnostic result is presented on a user-friendly digital interface, providing an immediate indication of potential health status.

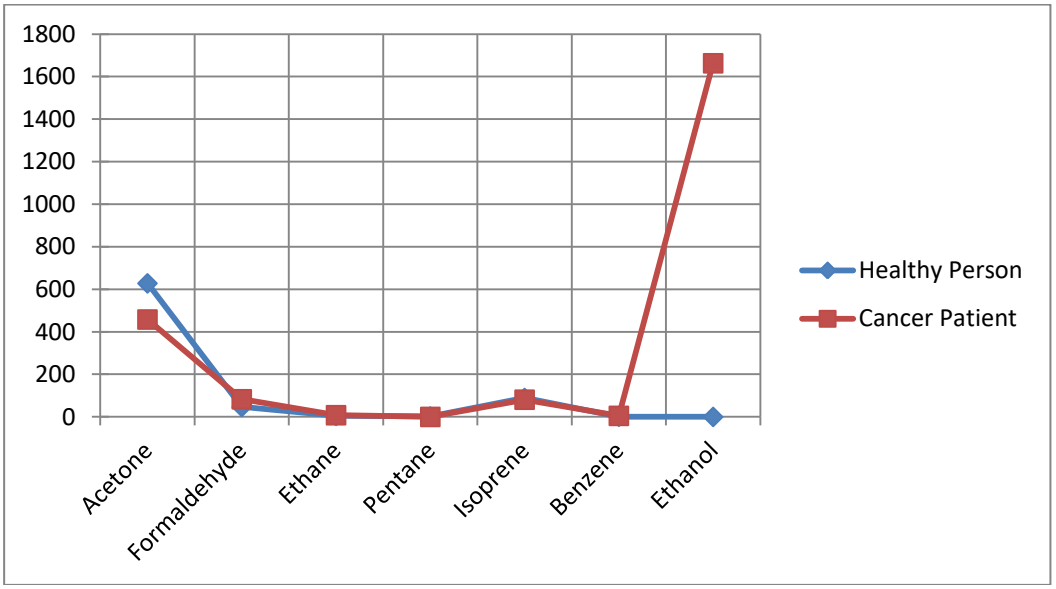


Fig.8.3 Line graph on Biomarkers present in healthy vs. Cancer Patients.

The study strictly adheres to ethical research standards, including obtaining informed consent from all participants and ensuring the confidentiality and security of collected data.

- **Ethical Considerations:** The development and deployment of the ODOScan device involve handling human breath samples, which requires careful attention to ethical standards. The following considerations will be addressed:

  - **Informed Consent** All participants will be briefed about the study objectives, procedures, potential risks, and benefits. Written informed consent will be obtained before collecting any breath samples.
  - **Ethical Approval** The study protocol will be submitted to the Institutional Ethics Committee (IEC) for review and approval prior to data collection. The study will comply with the guidelines of the Indian Council of Medical Research (ICMR) for biomedical research involving human subjects.
  - **Participant Privacy and Data Protection** Personal identifiers will be removed from collected data to ensure participant anonymity. Data will be securely stored and used strictly for research purposes. Only authorized personnel will have access to sensitive information.
  - **Non-Invasiveness and Safety** As ODOScan is a breath-based, non-invasive diagnostic tool, there are minimal physical or psychological risks to participants. All procedures will be designed to ensure

maximum comfort and safety.

- **Voluntary Participation and Withdrawal** Participants will be informed that their involvement is voluntary and they may withdraw from the study at any time without any consequences.
- **Use of Data and Results** The data will be used strictly for academic and scientific purposes, including publications, conference presentations, and system improvements. Results will be shared in aggregate form, without disclosing individual identities.

9. Statistical Plan:

Table 9.1. Statistical Plan for next three years

Sr. No.	Task	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)
1	Literature Review & Research Design	Months 1-6		
2	Data Collection & First Paper	Months 7-12	Months 13-16	
3	Data Analysis & Second Paper		Months 17-22	
4	Third Paper & Thesis Writing		Months 23-28	Months 29-36

10.Limitations of the Study (Future Scope):

Breath analysis is a relatively recent field of research with much promise in scientific and clinical studies. Breath contains endogenously produced VOCs resulting from metabolites of ingested precursors, gut and air-passage bacteria, environmental contacts, etc. Numerous recent studies have suggested changes in breath composition during the course of many diseases, and breath analysis may lead to the diagnosis of such diseases. Therefore, it is important to identify the disease-specific variations in the concentration of breath to diagnose the diseases.[31]

- **Age Groups: Result accuracy varies with the age/addiction of a person-** As people age, their metabolism undergoes changes which impact the types and amounts of VOCs produced. Participants with habits such as smoking, alcohol consumption, or gutkha chewing introduced variability in VOC profiles, potentially affecting diagnostic accuracy.
- **Environmental and dietary influences-**may alter breath VOC profiles and introduce noise in sensor readings.
- **Sample size constraints-** may affect the robustness and generalizability of the machine learning model.

- **Sensor drift and calibration issues-** over time can affect accuracy and repeatability.
- **Limited standardization-** of breath collection protocols across different sites.
- **Potential overlap of VOC signatures-** between lung cancer and other respiratory diseases may reduce specificity.

11. Expected Outcomes of Study: The proposed ODOScan system aims to deliver a cost-effective, portable, and non-invasive diagnostic tool for early detection of lung cancer. Upon successful completion of the project, the expected outcomes are:

- **Prototype Development**: A functional and portable breath analysis device integrating MOS, gas sensor arrays (e.g., 5C SSM) with embedded signal processing and machine learning capabilities.
- **VOC Pattern Detection**: Reliable identification and classification of disease-specific VOCs in exhaled breath validated using collected breath samples.
- **Machine Learning Model**: A trained and tested ML algorithm capable of distinguishing between healthy and potentially cancerous breath profiles with high sensitivity and specificity.
- **User Interface**: A simple graphical or mobile interface for clinicians or health workers to operate the device and interpret results in real time.
- **Field Readiness**: A validated proof-of-concept system suitable for preliminary deployment in clinics, health camps, or rural screening programs.

12. Bibliography:

1) Van den Vries, R., Farzan N., Fabius T., Dagelet Y. W. F., Jak P. M. C., Snoey Sterk P. J. (2025). **"**Lung cancer detection by electronic nose analysis of exhaled breath: A multicenter prospective external validation study." Annals of Oncology. Advance online publication. https://doi.org/10.1016/j.annonc.2025.03.013
2) Burger W, Gasparri R., Santonico M., Valentini C., Sedda G., Borri A., & Pennazza G. (2025)."Electronic-nose technology for lung cancer detection: A non-invasive diagnostic revolution." Lung, 203(3), 451–460. https://doi.org/10.1007/s00408-025-00828-0
3) Kononov A., Korotetsky B., Jahatspanian I., Gubal A., Vasiliev A., Arsenjev A., (2020)."Online breath analysis using metal oxide semiconductor sensors (electronic nose) for diagnosis of lung cancer. Journal of Breath Research.", 14(4), 046005. https://doi.org/10.1088/1752-7163
4) Kim C, Raja IS, Lee JM, Lee JH, Kang MS, Lee SH, Oh JW, Han DW. (2021)."Recent Trends in Exhaled Breath Diagnosis Using an Artificial Olfactory System." Biosensors (Basel); 11(9):337. doi: 10.3390/bios11090337.
5) Yuting Ji, Yunmeng Zhang, Siwen Liu, Jingjing Li, Qianyun Jin, Jie Wu, Hongyuan Duan, Xiaomin Liu, Lei Yang, Yubei Huang(2025), "The epidemiological landscape of lung cancer: current status, temporal trend and future projections based on the latest estimates from GLOBOCAN 2022." , Journal of the National Cancer Center, Volume 5, Issue 3,2025,Pages 278-286,ISSN 2667-0054, https://doi.org/10.1016/j.jncc.2025.01.003.
6) Tang, K.-T., & Chiu, S.-W. (2010). "A low-power electronic nose signal-processing chip for a portable artificial olfaction system." IEEE Transactions on Biomedical Circuits and Systems, 4(6), 379–386. https://doi.org/10.1109/TBCAS.2010.2049051
7) Szulejko J, McCulloch M, Jackson J, McKee D, Walker J and Solouki T.(2010). "Evidence for Cancer Biomarkers in Exhaled Breath." in IEEE Sensors Journal, vol. 10, no. 1, pp. 185-210, 10.1109/JSEN.2009.2035669 .
8) Zeh G., Koehne M., Grasskamp A., Haug H., Singh S., & Sauerwald T. (2022). "Towards Artificial Intelligent Olfactory Systems." Proceedings of the 2022 IEEE International Symposium on Olfaction and Electronic Nose (ISOEN), 1–4. https://doi.org/10.1109/ISOEN54818.2022.9792754
9) McWilliams A., Lam S., Le Riche J., MacAulay C., Gazdar A., & Phillips M. (2015). "Training and validating a portable electronic nose for lung cancer screening." Journal of Thoracic Oncology, *10*(5), 706–712. https://doi.org/10.1097/JTO.0000000000000502
10) Yager P., Domingo G. J., & Gerdes J. (2008)."Point-of-care diagnostics for global health." Nature, *442*(7101), 442–448. https://doi.org/10.1038/nature06996

11) Esteva A., Robicquet A., Ramsundar B., Kuleshov V., DePristo M., Chou K., Cui C., Corrado G., Thrun S., & Dean J. (2019). "A guide to deep learning in healthcare." *Nature Medicine, 25,* 24–29. https://doi.org/10.1038/s41591-018-0316-z

12) Balarajan Y., Selvaraj S., & Subramanian S. V. (2011). "Health care and equity in India". The Lancet, 377(9764), 505–515. https://doi.org/10.1016/S0140-6736(10)61894-6

13) Dragonieri S., Schot R., Mertens B. J., Le Cessie S., Gauw S. A., Spanevello A., Carratù P., Resta O., & Sterk P. J.(2007). "An electronic nose in the discrimination of patients with asthma and chronic obstructive pulmonary disease". Chest, *131*(4), 1235–1241. https://doi.org/10.1378/chest.06-1920

14) Gowda A. M. D., Dessai A. D., & Nayak U. Y. (2025). "Electronic-nose technology for lung cancer detection: A non-invasive diagnostic revolution." Lung, 203, Article 76. https://doi.org/10.1007/s00408-025-00828-0

15) Leja M., Šipilova A., & Funka K. (2018). "Breath biopsy: Towards early detection of cancer and infectious diseases."European Journal of Cancer Prevention, *27*(2), 179–180. https://doi.org/10.1097/CEJ.0000000000000421

16) Ma T. T., Chang Z., Zhang N., et al. (2024). "Application of electronic nose technology in the diagnosis of gastrointestinal diseases: A review". Journal of Cancer Research and Clinical Oncology, 150*(1)*, 401. https://doi.org/10.1007/s00432-024-05925-w

17) Sharma A., Kumar R., & Varadwaj P. (2023). "Smelling the disease: Diagnostic potential of breath analysis**."** Molecular Diagnosis & Therapy, 27, 321–347. https://doi.org/10.1007/s40291-023-00640-7

18) Abideen Z. UL., Arifeen W. UL., Bandara D. Y, Nuwan Y.M. (2024). "Emerging trends in metal oxide-based electronic noses for healthcare applications: a review". Nanoscale, *16*, 9259–9283. https://doi.org/10.1039/D4NR00073K

19) Vadala R., Pattnaik B., Bangaru S., Rai D., Tak, J., Kashyap S., Verma U., Yadav G., Dhaliwal R., Mittal S., Hadda V., Madan K., Guleria R., Agrawal A., & Mohan A. (2023). "A review on electronic nose for diagnosis and monitoring treatment response in lung cancer." Journal of breath research, *17*(2), 10.1088/1752-7163/acb791. https://doi.org/10.1088/1752-7163/acb791

20) Huang Y., Doh I.-J., & Bae E. (2021). "Design and Validation of a Portable Machine Learning-Based Electronic Nose". Sensors, 21(11), 3923. https://doi.org/10.3390/s21113923

21) Karakaya D., Ulucan O. & Turkan M. "Electronic Nose and Its Applications: A Survey". Int. J. Autom. Comput." 17, 179–209 (2020). https://doi.org/10.1007/s11633-019-1212-9

22) odour sensing Dennler N., Drix D., Warner T. P. A., Rastogi S., Casa C. D., Ackels T., van Schaik A, Schmuker M. (2024). "High-speed using miniaturised electronic nose". IEE Proceedings - Science, Measurement and Technology, vol. 150, no. 2, pp. 76–80, Mar. 2003, doi: 10.1049/ip-smt:20030247

23) Broza Y. Y., Vishinkin R., Barash O., Nakhleh M. K., Haick H. (2020).”Multiplexed nanomaterial-based sensor array for detection of COVID-19 in exhaled breath.” *ACS Nano*, *14*(6), 6912–6924. https://doi.org/10.1021/acsnano.0c05657

24) van der Sar I. G, N. Wijbenga G. Nakshbandi, Aerts J. G. J. V., Manintveld O.C, Wijsenbeek M. S., Hellemons M. E. & Moor C. C. (2004). “A review of the current status of electronic nose technology.” Respiratory Research, 5(1), 28. https://doi.org/10.1186/rr660

25) Fens N., Zwinderman A. H., van der Schee M. P., de Nijs S. B., Dijkers E., Roldaan A. C., Cheung D., Bel E. H., & Sterk P. J. (2009).” Exhaled breath profiling enables discrimination of chronic obstructive pulmonary disease and asthma.” American journal of respiratory and critical care medicine, *180*(11), 1076–1082. https://doi.org/10.1164/rccm.200906-0939OC

26) Chen C. D., Zheng Y. X., Lin H. F., & Yang H. Y. (2025). “Development of Electronic Nose as a Complementary Screening Tool for Breath Testing in Colorectal Cancer.” Biosensors, 15(2), 82. https://doi.org/10.3390/bios15020082

27) Yuting Ji, Yunmeng Zhang, Siwen Liu, Jingjing Li, Qianyun Jin, Jie Wu, Hongyuan Duan, Xiaomin Liu, Lei Yang, Yubei Huang (2025), ”The epidemiological landscape of lung cancer: current status, temporal trend and future projections based on the latest estimates from GLOBOCAN 2022” , Journal of the National Cancer Center, Volume 5, Issue 3,2025,Pages 278-286,ISSN 2667-0054, https://doi.org/10.1016/j.jncc.2025.01.003.

28) Amal H., Leja M., Funka K., Skapars R., Sivins A., Ancans G., Liepniece-Karele I., Kikuste I., Lasina I., & Haick H. (2016).” Detection of precancerous gastric lesions and gastric cancer through exhaled breath.” Gut, *65*(3), 400–407. https://doi.org/10.1136/gutjnl-2014-308536

29) Phillips, M., Cataneo, R. N., Cummin, A. R., Gagliardi, A. J., Gleeson, K., Greenberg, J., ... & Wai, J. (2003). Volatile organic compounds in breath as markers of lung cancer: a cross-sectional study. *The Lancet*, 359(9308), 930–935. https://doi.org/10.1016/S0140-6736(02)08028-3

30) Peng, G., Tisch, U., Adams, O., Hakim, M., Shehada, N., Broza, Y. Y., ... & Haick, H. **(2009).** Diagnosing lung cancer in exhaled breath using gold nanoparticles. *Nature Nanotechnology*, 4(10), 669–673. https://doi.org/10.1038/nnano.2009.235

31) Amann, A., Costello, B. D. L., Miekisch, W., Schubert, J., Buszewski, B., Pleil, J., ... & Risby, T. (2014). The human volatilome: volatile organic compounds (VOCs) in exhaled breath, skin emanations, urine, feces and saliva. *Journal of Breath Research*, 8(3), 034001. https://doi.org/10.1088/1752-7155/8/3/034001

32) Bhandari, R., & Dey, S. (2022, October 18). IIT Roorkee researchers develop affordable breath-basedcancer detector. *https://www.hindustantimes.com/education/news/iit-roorkee-researchers-develop-breath-based-cancer-detector-101666088187283.html*

33) IIT Bombay. (2018). “Sniffing out lung cancer using nanotechnology-enabled breath analysis.” Indian Institute of Technology Bombay. https://www.iitb.ac.in/en/research-highlight/sniffing-out-lung-cancer-using-nanotechnology-enabled-breath-analysis

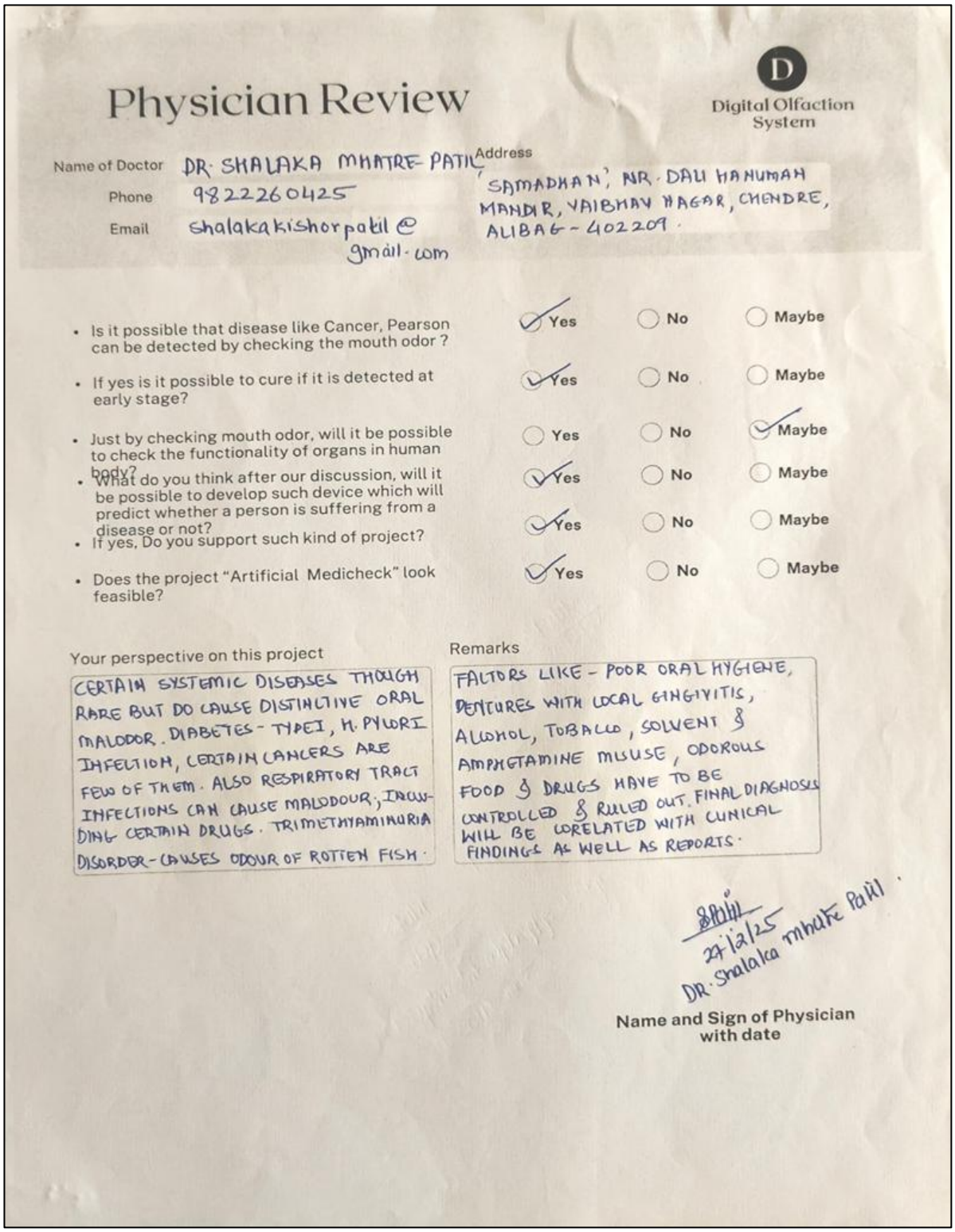
34) IIT Kanpur (2023). “Novel portable technology developed for continuous lung health monitoring” [Press release]. https://www.iitk.ac.in/new/novel-technology-for-lung-health-monitoring

35) Owlstone Medical, “Breath Biopsy® OMNI®: Advanced global breath VOC analysis.” [Online]. https://www.owlstonemedical.com/products/breath-biopsy-platform/breath-biopsy-omni/

36) Aroma Bit Sensor technology, for 5CSSM Sensor;https://www.aromabit.com/wp-content/uploads/2025/07/5CSSM_EN_v5.7.pdf

13.Appendix:

To assess the clinical feasibility, acceptance, and practical challenges associated with implementing a non-invasive, AI-based breath diagnostic tool (ODOScan), a structured survey was conducted among medical practitioners. It presents the feasibility, and insights obtained from the survey with medical-practitioners.



Physician Review

Digital Olfaction System

Name of Doctor: DR. SHALAKA MHATRE-PATIL

Address: 'SAMADHAN', NR. DALI HANUMAN MANDIR, VAIBHAV NAGAR, CHENDRE, ALIBAG - 402209.

Phone: 9822260425

Email: shalakakishorpatil@gmail.com

	Yes	No	Maybe
• Is it possible that disease like Cancer, Pearson can be detected by checking the mouth odor ?	✓		
• If yes is it possible to cure if it is detected at early stage?	✓		
• Just by checking mouth odor, will it be possible to check the functionality of organs in human body?			✓
• What do you think after our discussion, will it be possible to develop such device which will predict whether a person is suffering from a disease or not?	✓		
• If yes, Do you support such kind of project?	✓		
• Does the project "Artificial Medicheck" look feasible?	✓		

Your perspective on this project

CERTAIN SYSTEMIC DISEASES THOUGH RARE BUT DO CAUSE DISTINCTIVE ORAL MALODOR. DIABETES - TYPE I, H. PYLORI INFECTION, CERTAIN CANCERS ARE FEW OF THEM. ALSO RESPIRATORY TRACT INFECTIONS CAN CAUSE MALODOUR; INGESTING CERTAIN DRUGS. TRIMETHYAMINURIA DISORDER - CAUSES ODOUR OF ROTTEN FISH.

Remarks

FACTORS LIKE - POOR ORAL HYGIENE, DENTURES WITH LOCAL GINGIVITIS, ALCOHOL, TOBACCO, SOLVENT & AMPHETAMINE MISUSE, ODOROUS FOOD & DRUGS HAVE TO BE CONTROLLED & RULED OUT. FINAL DIAGNOSIS WILL BE CORELATED WITH CLINICAL FINDINGS AS WELL AS REPORTS.

27/12/25

DR. Shalaka Mhatre Patil.

Name and Sign of Physician with date

Ocologist

cian Review

D
Digital Olfaction System

Nilesh Chordiya. Address

2496045 7

Dr. Nilesh Chordiya
Consultant Surgical Oncologist
MS, FIAGES, FMAS (Seoul South Korea)
Tata Trained Cancer Surgeon
Specialty: Gastro-Intestinal and Gynecologic Cancers, Pancreatic Cancer, Laparoscopic Cancer Surgery, Urological Cancer Surgeries, Thoracoscopic Esophagus and Lung Surgery
Branches :
Andheri | Charni Road | Ghatkopar (W)
Mulund | Thane

disease like Cancer, Pearson y checking the mouth odor ?	○ Yes	○ No	✓ Maybe
to cure if it is detected at	✓ Yes	○ No	○ Maybe
• Just by checking mouth odor, will it be possible to check the functionality of organs in human body.	○ Yes	○ No	✓ Maybe
• What do you think after our discussion, will it be possible to develop such device which will predict whether a person is suffering from a disease or not?	○ Yes	○ No	✓ Maybe
• If yes, Do you support such kind of project?	✓ Yes	○ No	○ Maybe
• Does the project "Artificial Medicheck" look feasible?	✓ Yes	○ No	○ Maybe

Your perspective on this project	Remarks
- possible to detect recurrent cancer. by exfoliated cells in breast by genetic / AI assessment assessment cells.	please develop at earlier & all the best

Name and Sign of Physician with date

Dr. Nilesh S. Chordiya
M.S., FIAGES., FMAS (Korea)
Onco Surgery (Ex. Tata Hospital)
Reg. No. 2000010124
Consultant Cancer Surgeon

19th April 2025

BLOOM
Maternity Home & Advanced Laparoscopy Centre

Plot No.261-A, Sector 3F,
Airoli, Navi Mumbai - 400 708.
Tel. 02227791312, 02227791311
Mob. : 9004858544

Dr. Girish Sawant
M.B.B.S., D.G.O. (Mumbai), FCPS
Consultant Obstetrician and Gynaecologist

Dr. Dipal Sawant
M.B.B.S., D.A. (Mumbai)
Consultant Anaesthesiologist

ew

'ANT Address

gmail.com

D
Digital Olfaction System

• Is it possible that disease like Cancer, Pearson can be detected by checking the mouth odor ?	✓ Yes	○ No	○ Maybe
• If yes is it possible to cure if it is detected at early stage?	✓ Yes	○ No	○ Maybe
• Just by checking mouth odor, will it be possible to check the functionality of organs in human body.	○ Yes	○ No	✓ Maybe
• What do you think after our discussion, will it be possible to develop such device which will predict whether a person is suffering from a disease or not?	○ Yes	○ No	✓ Maybe
• If yes, Do you support such kind of project?	○ Yes	○ No	✓ Maybe
• Does the project "Artificial Medicheck" look feasible?	○ Yes	○ No	✓ Maybe

Your perspective on this project	Remarks
Looks a promising project. If such system can be developed, it will be a big boost for early diagnosis of the concerned condition.	Being non-invasive it will have more acceptance. Test should be with high specificity & sensitivity.

Name and Sign of Physician with date
(Dr. Girish Sawant)

BLOOM
MATERNITY HOME &
ADVANCED LAPAROSCOPY CENTRE
PLOT NO. 261-A, SEC- 3F, AIROLI.

02/3/2025

Physician Review

Digital Olfaction System

Name of Doctor: Dr Mohan Ranawade

Address: Ranawad Hospital, Akluj

Phone:

Email: mrnhicu@gmail.com

• Is it possible that disease like Cancer, Pearson can be detected by checking the mouth odor ?	✓ Yes	○ No	○ Maybe
• If yes is it possible to cure if it is detected at early stage?	✓ Yes	○ No	○ Maybe
• Just by checking mouth odor, will it be possible to check the functionality of organs in human body.	✓ Yes	○ No	○ Maybe
• What do you think after our discussion, will it be possible to develop such device which will predict whether a person is suffering from a disease or not?	✓ Yes	○ No	○ Maybe
• If yes, Do you support such kind of project?	✓ Yes	○ No	○ Maybe
• Does the project "Artificial Medicheck" look feasible?	✓ Yes	○ No	○ Maybe

Your perspective on this project	Remarks
feasible, but depends on Sensor Array, Sampling & Algorithm Technology has to be specific and Sensitive.	Project should be worked

Name and Sign of Physician with date

28/4/2025

13.1 Medical Practitioner Survey on Feasibility of ODOScan

With**Dr. Shalaka Patil**
(MBBS Medicine)
Chief Manager Medical.
Practitioner at RCF Hospital

With **Dr. Nilesh S. Chordiya**
(M.S., FIAGES,FMAS(Korea)
Onco Surgery(Ex. TATA Hosp.)
at SSO Speciality, Thane

With **Dr. Girish Sawant**
(M.B.B.S., DGO, FCPS(Mumbai),
Consultant Obstetrician &
Gynecologist, at Bloom
Maternity Home, Airoli

With **Dr. Mohan Ranawade**
(M.B.B.S., M.D.(Medicine),
at Ranawade Hospital,
Alibag

With **Dr. Vinit Shinde**
(M.D. Medicine)
General Physician at Laxmi ICU
& Nursing Center

Volatile Organic Compound Profiling with biomarkers for Early Lung Cancer Detection using the ODOScan E-Nose System

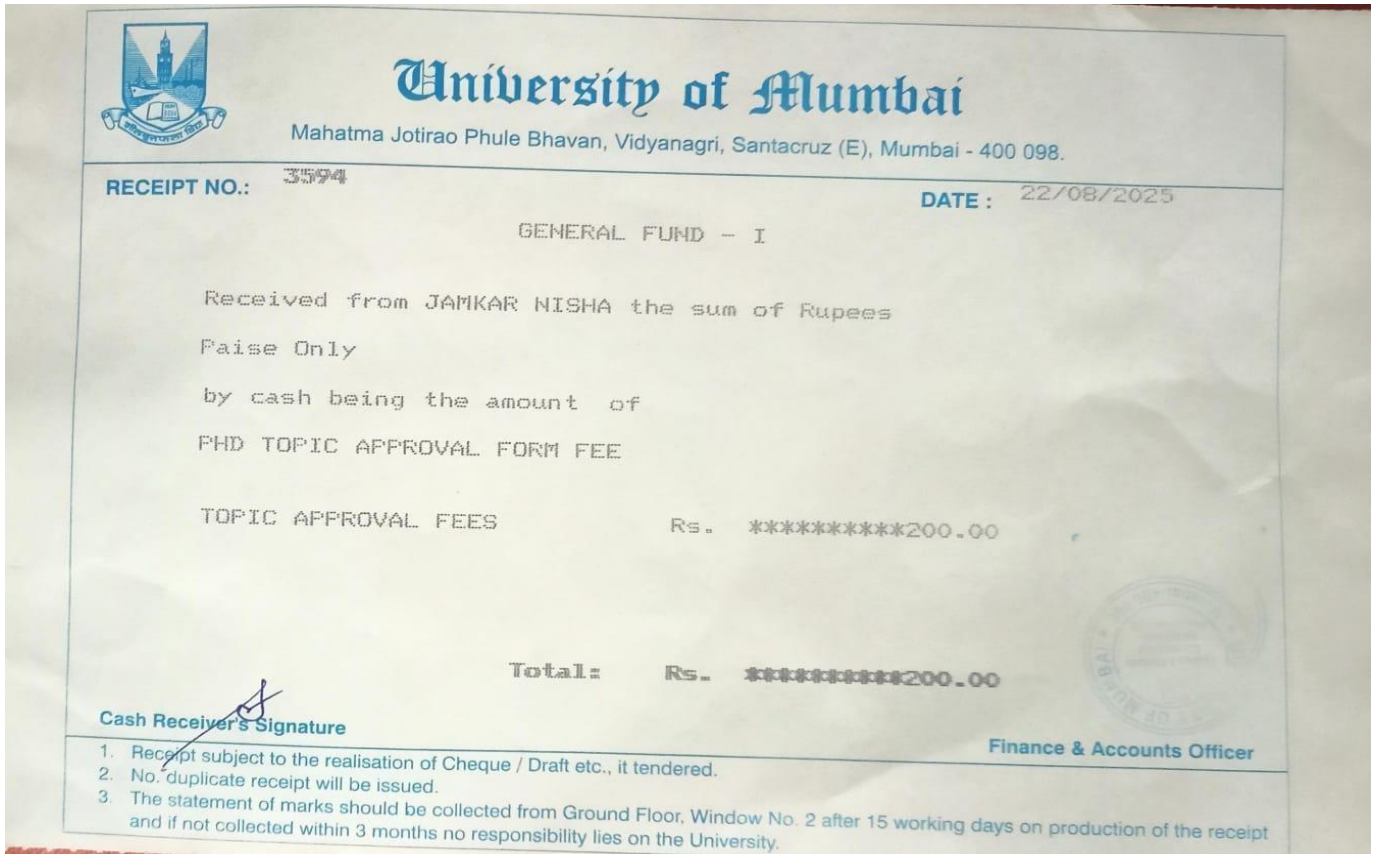
ORIGINALITY REPORT

7%	3%	4%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Arzoo Saini, Neelam Yadav. "A new paradigm of e-NOSE technology for the non-invasive and early lung cancer diagnostics", Chemical Engineering Journal, 2025 Publication	2%
2	"Abstracts", Journal of Thoracic Oncology, 2009 Publication	1%
3	Submitted to University of West London Student Paper	<1%
4	www.mdpi.com Internet Source	<1%
5	www.americaspg.com Internet Source	<1%
6	www.hnjournal.net Internet Source	<1%
7	www.dovepress.com Internet Source	<1%
8	www.drmgrdu.ac.in Internet Source	<1%
9	www.cancernetwork.com Internet Source	<1%
10	Submitted to Middlesex University Student Paper	<1%
11	jmhg.springeropen.com Internet Source	<1%
12	Submitted to Management Resources College Student Paper	<1%
13	simplywall.st Internet Source	<1%
14	www.researchgate.net Internet Source	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		



University of Mumbai

Mahatma Jotirao Phule Bhavan, Vidyanagri, Santacruz (E), Mumbai - 400 098.

RECEIPT NO.: 3594 **DATE :** 22/08/2025

GENERAL FUND - I

Received from JAMKAR NISHA the sum of Rupees

Paise Only

by cash being the amount of

PHD TOPIC APPROVAL FORM FEE

TOPIC APPROVAL FEES	Rs.	**********200.00
Total:	**Rs.**	**********200.00**

Cash Receiver's Signature

Finance & Accounts Officer

1. Receipt subject to the realisation of Cheque / Draft etc., it tendered.
2. No. duplicate receipt will be issued.
3. The statement of marks should be collected from Ground Floor, Window No. 2 after 15 working days on production of the receipt and if not collected within 3 months no responsibility lies on the University.